Theoretical uncertainties in the WW background in Higgs searches

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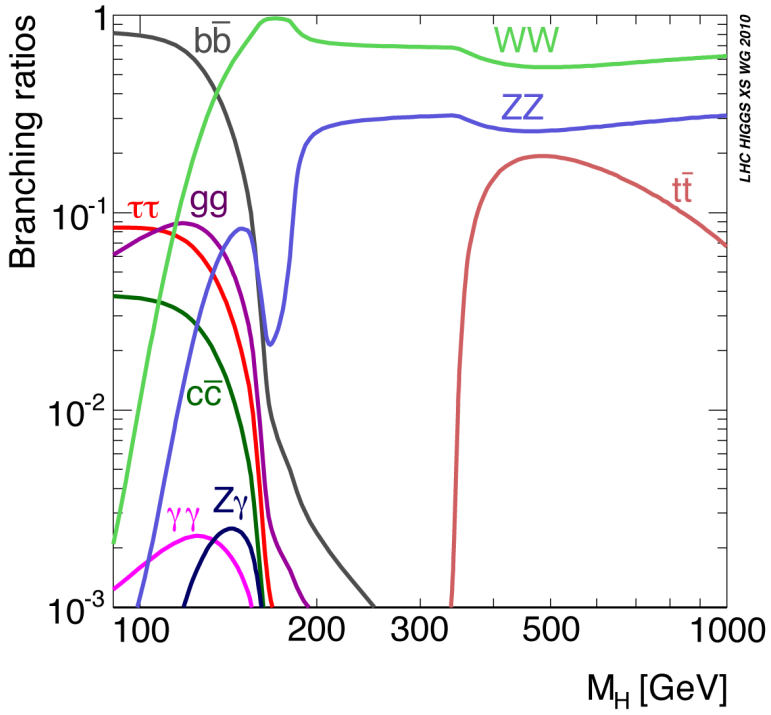
Higgs search in H → WW

$H \to W^+W^-$ is an important channel for Higgs search at the LHC

Interesting final state is $W^+W^- \to l\,\nu_l\,l\,\nu_l$ because leptons are easy to reconstruct
(Here l = e, μ)



Two neutrinos make precise reconstruction of Higgs difficult

Higgs search in H → WW, Backgrounds

Select events with $2l + E_T^{miss}$ (e^+e^-, $\mu^+\mu^-$, $e^\pm\mu^?$)

Other processes with this signature:

- WW (irreducible background)
- tt, tW
- $Z / \gamma^* \rightarrow 2l$
- $W\gamma$, WZ, ZZ
- W + jets
- QCD multijets

Lepton selection

- Select events with two oppositely-charged leptons

- Muons:
  - $p_T > 10$ GeV, $|\eta| < 2.4$
  - Reconstructed either from matching tracks in silicon detector with tracks in muon system or a global fit on all hits
  - Minimum number of hits, consistent with particle originating from primay Vertex

- Electrons:
  - $p_T > 10$ GeV, $|\eta| < 2.5$
  - Reconstructed from ECAL hits matched with a track from silicon detector
  - Bremsstrahlung effects taken into account in reconstruction

- Lepton isolation: Cone around track with $\Delta R < 0.3$ (0.4) for μ (e)

$$\sum_C E_T / p_T^l < 0.1$$

WW pair background

WW (+ jets) is a major background in this Higgs search

Need a good understanding of this background to separate from signal

Data-driven background estimation: fit MC prediction for dilepton mass at high values to data, extrapolate to lower masses (signal region)

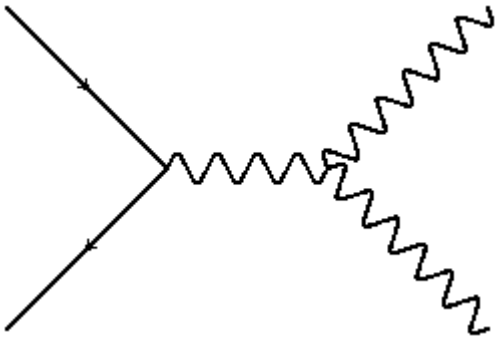
Extrapolation uncertainty

How good is this extrapolation?

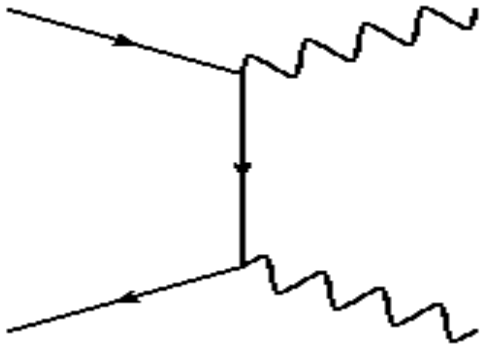
- Crucial to compare with NLO calculations to check k-Faktor over complete $m_{\|}$ range
- Investigate uncertainties on distributions using NLO MC (implemented in VBFNLO)

Scale choice

- What is a “good” choice?
- Problem: different types of diagrams contribute



Q^2, m_{WW}: “natural scale”



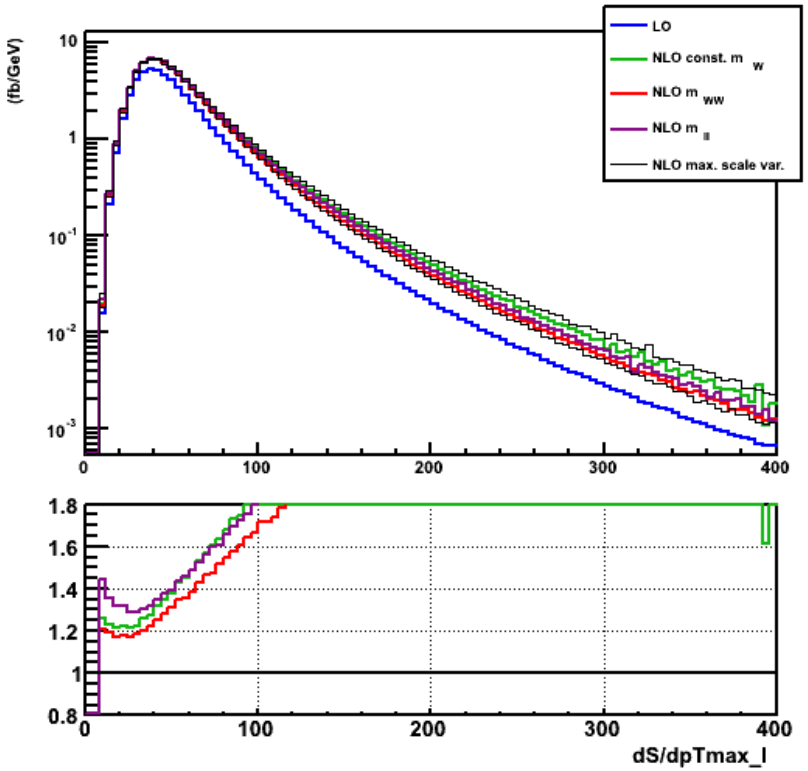
no obvious scale choice

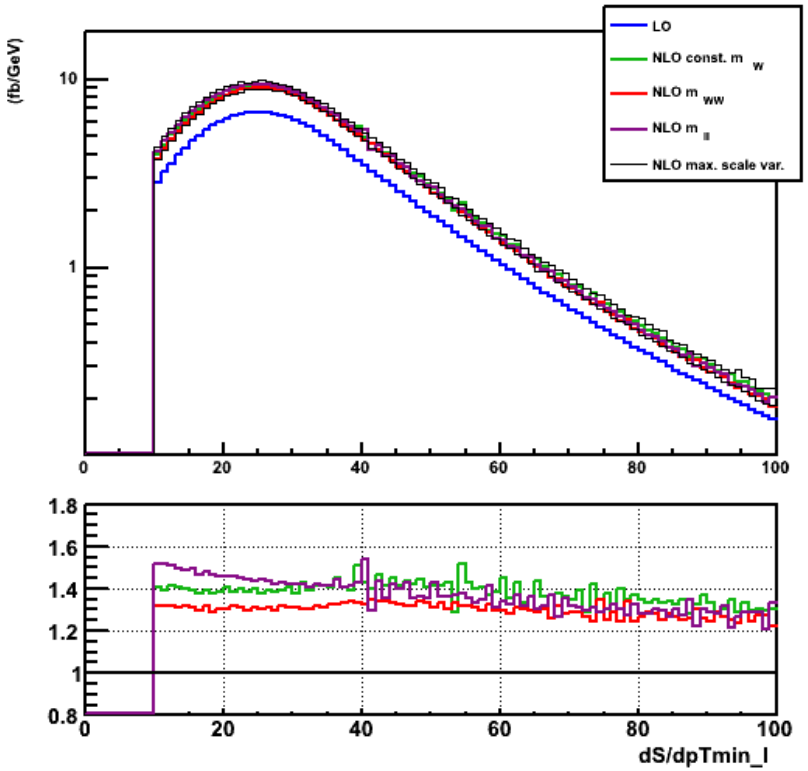
Scales

- Try all kinds of different scale choices and vary them to see the influence of the choice
  - Q^2, M_{WW}
  - $\mathrm{Min}(E_T^W)$
  - M_W, $\min(q_1^2, q_2^2)$
  - M_{ll}
- Especially interesting to see differential k-factors in m_{ll}

Leptons

Check description of individual leptons





Hardest Lepton

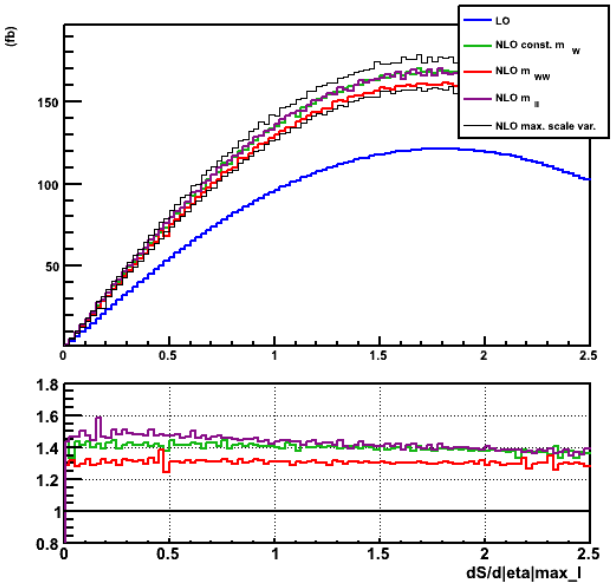
Second Lepton

Lepton transverse momentum

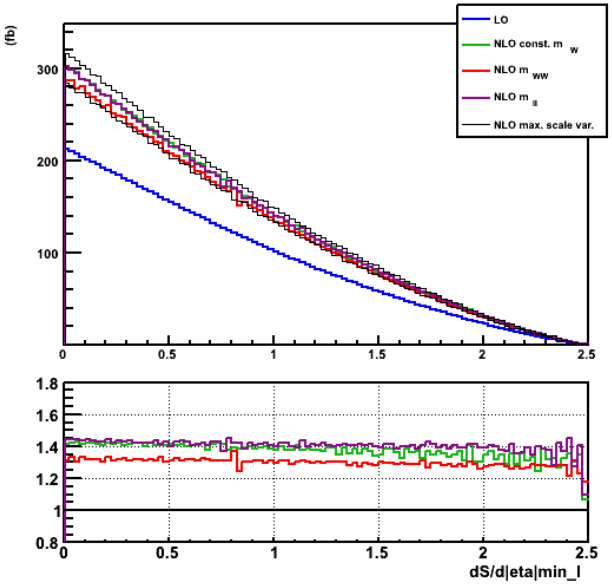
Leptons and Missing E_T

- Lepton rapidity

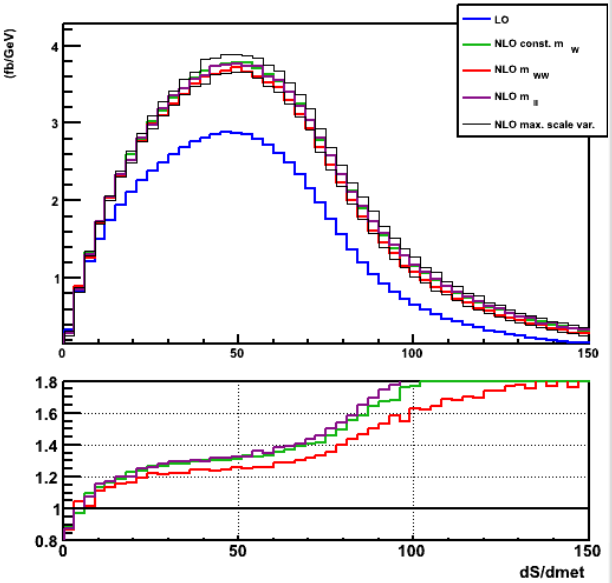
hardest lepton



2^{nd} hardest lepton

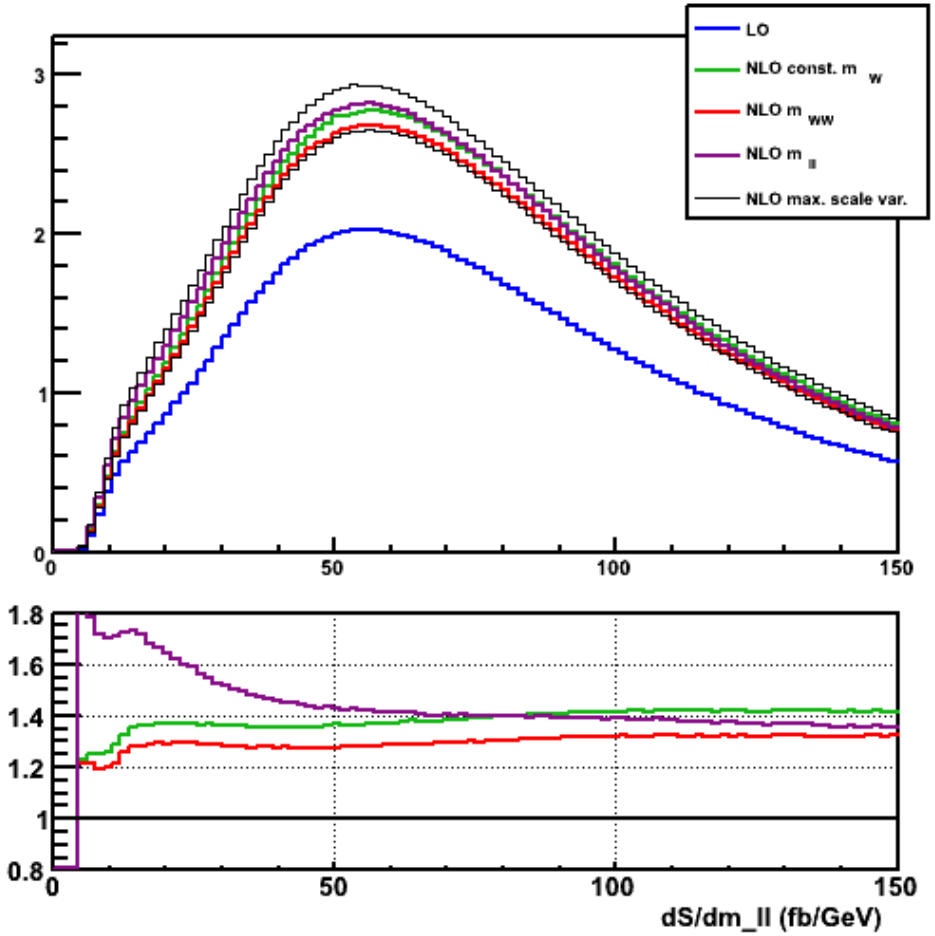


Missing E_T



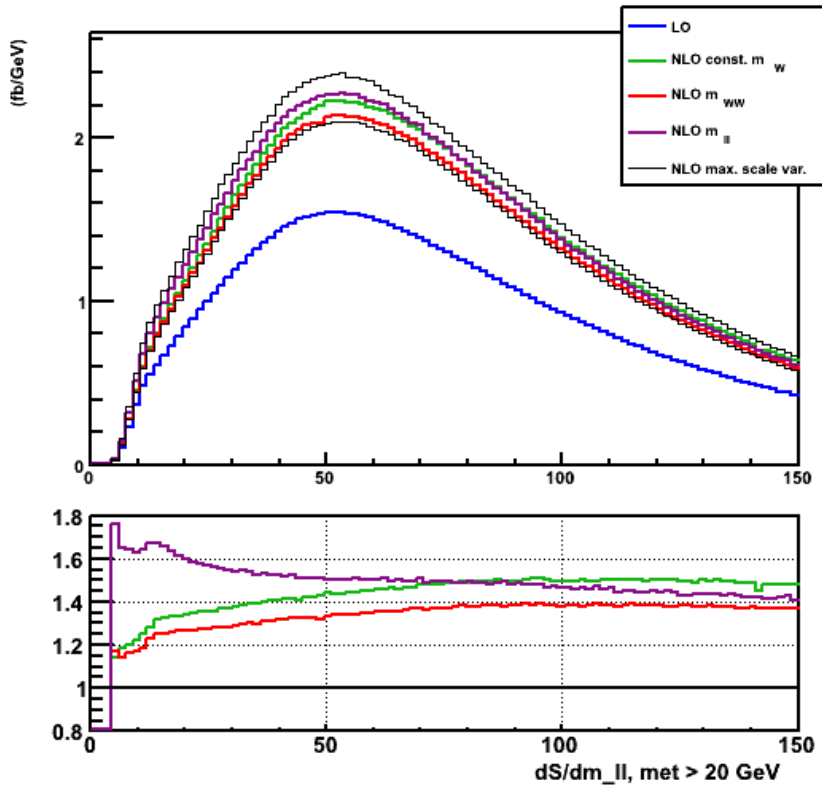
Dilepton mass

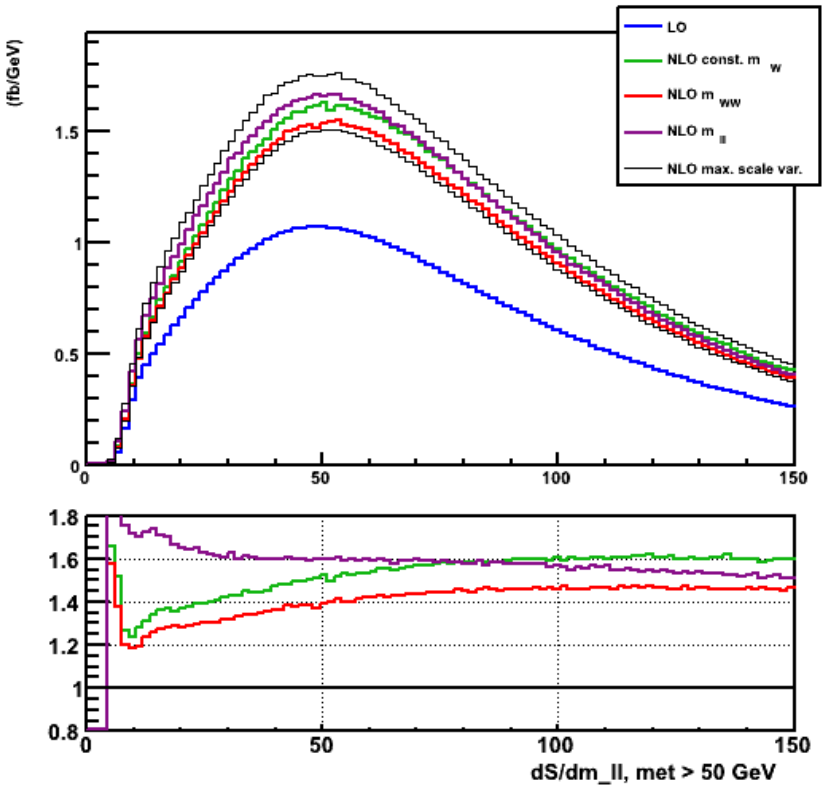
- Stable k-Faktor in most cases but scale uncertainty not negligible



Dilepton mass w/ MET cut

- Change in m_{ll} after cuts on E_T^{miss}





$E_t^{miss} > 20$ GeV

$E_t^{miss} > 50$ GeV

Analysis cuts

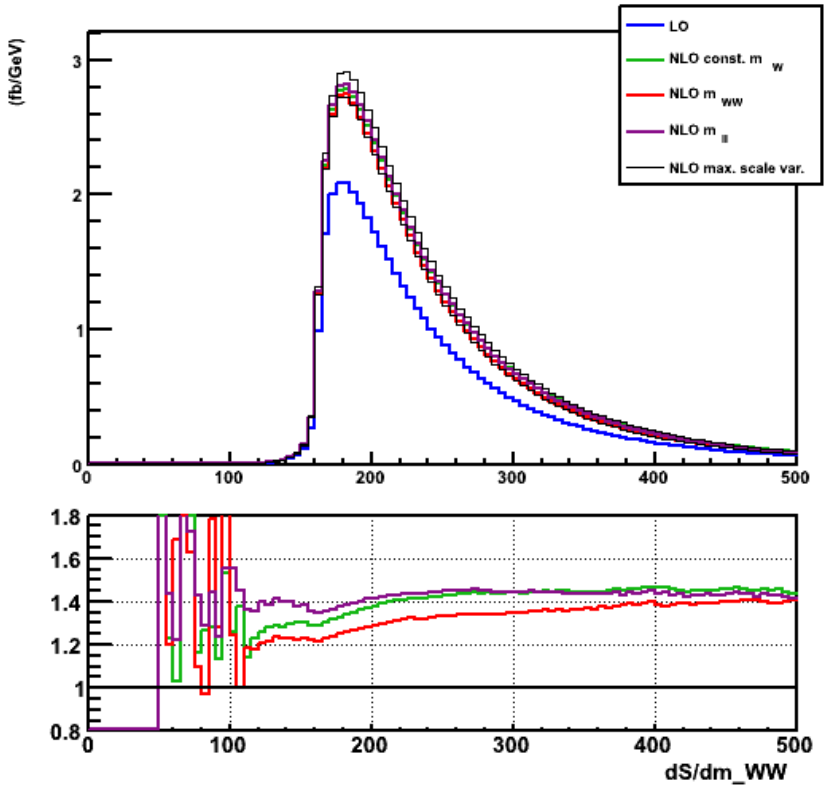
- Cuts to reduce backgrounds, dependent on Higgs mass
  here: m_H=130 GeV
  - $p_T^{l,max} > 25$ GeV, $p_T^{l,min} > 10$ GeV
  - $M_{ll} < 45$ GeV
  - $\Delta\varphi_{ll} < 90°$
  - $m_T^{ll,ETmiss}$ in [75, 125] GeV

- How do these cuts influence the WW background?

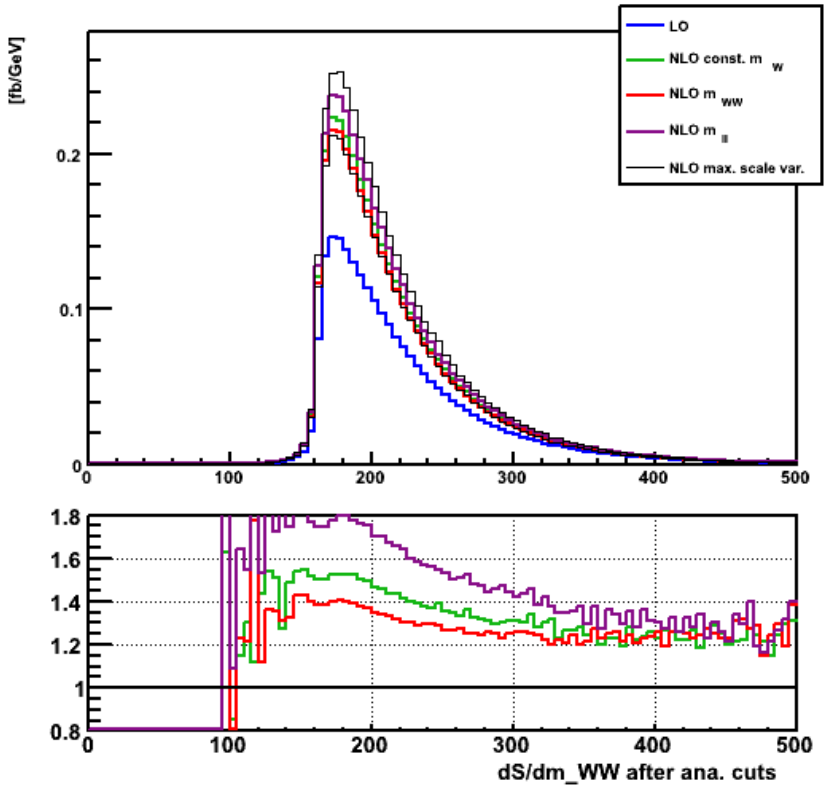
WW mass

- Invariant WW mass

without cuts



with analysis cuts

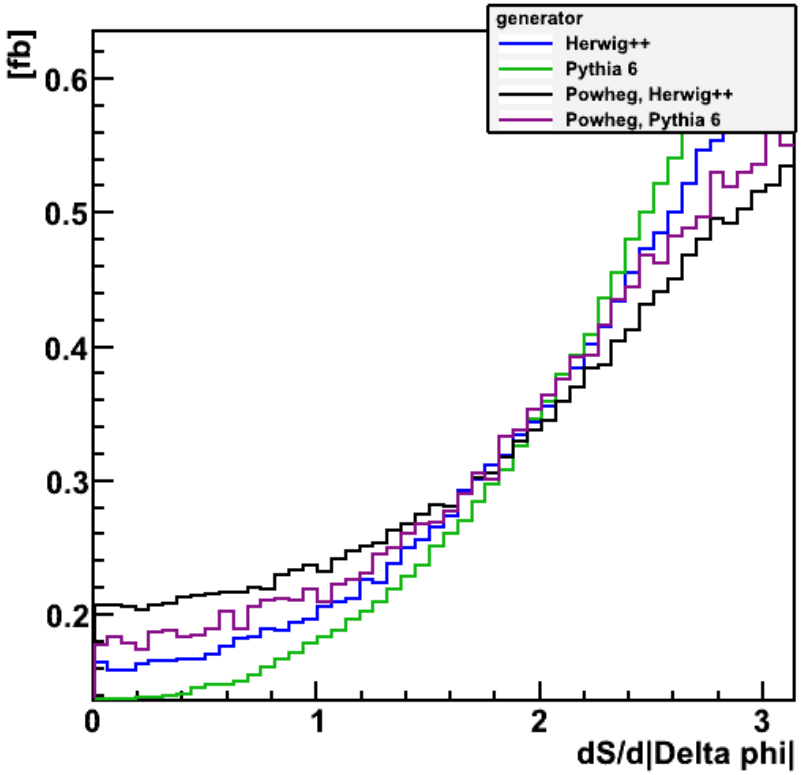


Background extrapolation

- WW background is estimated from data by extrapolating the dilepton mass from values M_{ll} > 100 GeV

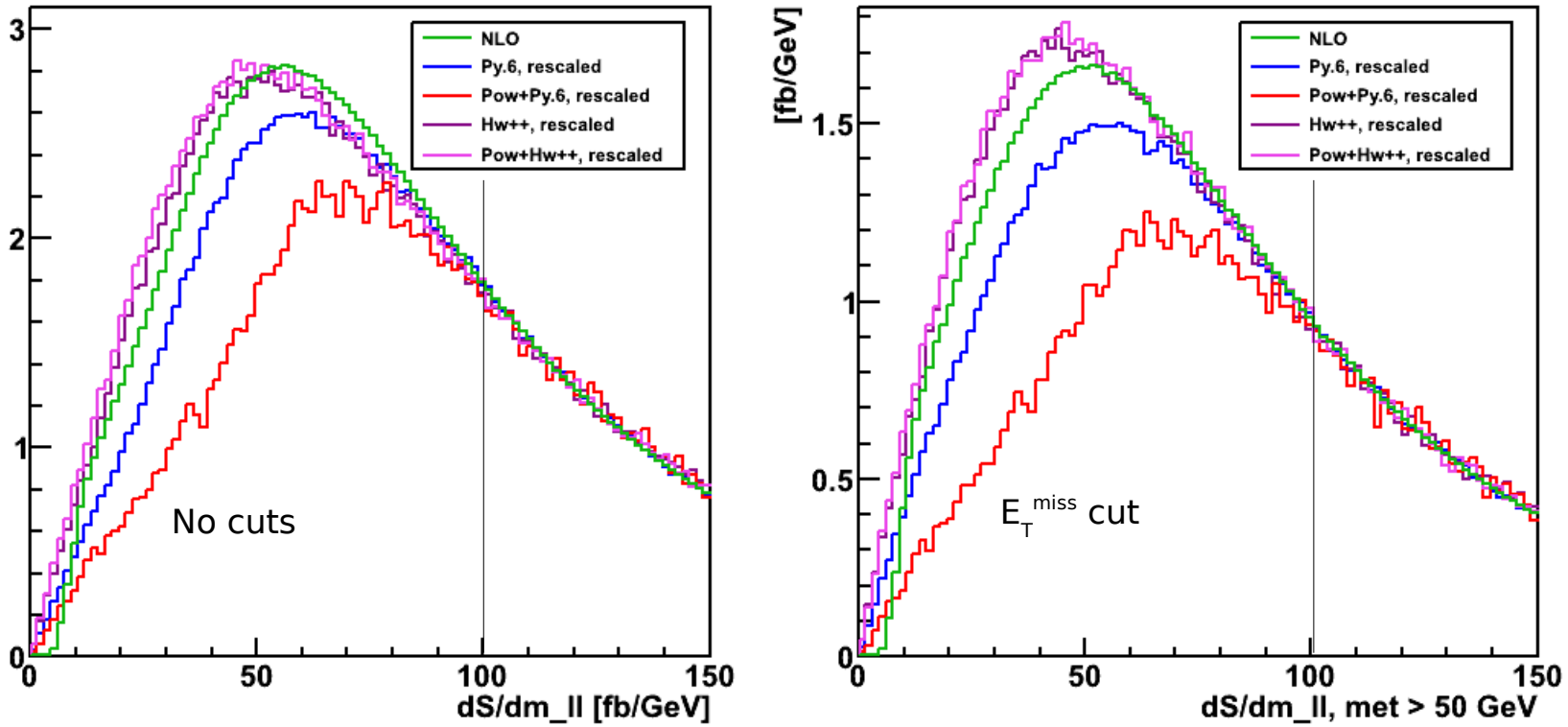
- Compare NLO distribution with Pythia, Herwig++ (LO) and POWHEG prediction, rescaled to NLO

- Spin correlations should be included in W decay



Background extrapolation

- Fit Shower Monte Carlo to NLO prediction (vbfnlo) in high mass region (only ME + shower, no Hadro.,UE)



Powheg + Pythia includes MI, not possible to turn of in Powheg Box

Conclusion

- NLO corrections to WW production yield a (mostly) constant k-Factor
- Scale choice not trivial, overall effect in O(10%) region, but probably sizable impact on differential k-Factor
- Fitting MC to data requires full description of W boson decay spin correlations
- Extrapolation used in WW background estimation probably more uncertain than assumed